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Abstract

We do not know yet if superconductivity will become useful without refrigeration. Now the superconductors are so different from copper that it is difficult to imagine replacing copper with such a brittle material. Superconductors conduct dc with no loss, ac with small losses, and microwaves in co-axial lines with almost no loss and with no dispersion from dc to the highest frequencies. They will probably allow us to close the gap between radio frequency and infra red optical transmission. Clearly your industry should know some things about where superconductivity may lead us and must consider whether the greater risk is to develop them or to let others try it. There are no easy answers yet.

Introduction

There are now materials that become superconducting at a critical temperature T_c of just under 100 K (-173°C), which the previous speaker, P. H. Hor, helped to discover. This discovery just made this year, is now one of the most widely confirmed discoveries ever made. At this temperature, cooling with liquid nitrogen or refrigerators is far more economical than for previously known superconductors. Nonetheless, except for rather high tech devices, these new materials may not have great impact because cooling remains necessary. We continue to read in the popular press about T_c's as high as room temperature. It is fair to say that most laboratories have seen evidence of these higher temperatures, which disappear in hours or days. Either we will find out what rather unstable, trace chemical compound in our samples is the room temperature superconductor or we will convince ourselves that these are only indications of our difficulty in making measurements on a ceramic. If room temperature superconductivity (actually it is best to work at or below 3/4 of T_c) is achieved, the technology will so enter our daily lives as to genuinely change society.

To the wire and cable industry, the course of action is not obvious. The research is moving at a record pace, but the refrigeration still required limits widespread applications. It seems clear that the electronics industry will be using these superconductors for yet another revolution. This could fundamentally alter the way information is transmitted. It seems appropriate to mention that after the transistor was invented, its use to replace vacuum tubes was considered a great breakthrough. What has since come from the transistor was not forseen. We must now determine, and to some extent bet our resources, on whether we are in this situation again.

Materials

These superconducting compounds are made of a stoichiometric mix of (1) an alkaline earth, say barium, (2) a rare earth or mixture of them, say yttrium, europium, gadolinium, and (3) copper that is partially oxidized. These elements are not particularly expensive or hard to find, and they are not toxic or hazardous. This mix is usually obtained by grinding together oxides and carbonates or by precipitating water soluble forms. This is followed by one or more sequences of grinding, compacting, firing in air or oxygen at about 950°C, and slow cooling. This basic preparation can now be performed by an overwhelming array of specific processes. It thus seems clear that different applications will each use the most optimal process. All of this is necessary to make what will replace copper in many applications and the next speaker will expand on this.

The resulting superconductor will break if you drop it on a hard surface. Various cladding procedures or use of fine fibers (like optical fibers) can improve on this. But remember that like the transistor, we may not need a direct replacement for plain old copper wire. For example, quite likely, coils could be manufactured as monolithic ceramics where firing is the final step.

Overall the progress on producing these materials has proceeded at an unprecedented rate because of the large number of workers around the world. I will give a few examples of perceived problems that are being solved In general, this is why I present no list of problems. The high temperature firing is a difficult production step, and any semiconductors that are to be married to the superconductor would not survive. Recently Bell Communications Research has reported that a treatment in an oxygen plasma at room temperature can replace the firing. Although this currently takes many hours, it is an impressive step forward. It is difficult to make a connection between the superconductor and a conventional conductor. On the other hand a transformer with a copper primary and a superconducting secondary will work fine if the bandwidth is adequate. Also the fabrication of more components from ceramics can eliminate this problem.

The biggest limitation on the present materials that may be fundamental, that is not fixable, is the current carrying capacity. If room temperature superconductors are found it seems likely that they will have this same limitation. Near the T_c, currents roughly of the capacity of copper wire destroy the superconductivity. The older, lower T_c materials can easily carry a thousand times the current that copper can. While higher currents are being vigorously sought, it is important to note that for communications, the present ratings are more than adequate.

High Frequency

If you set resistance equal to zero in your transmission equations, you find that dispersion vanishes. If you make the gap narrow in a co-axial line you find that a superconducting delay line can be 20 times shorter. At high frequencies, the fact that the present materials are superconducting grains connected by poorer conductors is solved by capacitive coupling. Superconducting switching circuits have always been much faster than semiconductors (and are orders of magnitude less sensitive to radiation damage). Shielding made of superconductors works down to dc. The word bandwidth can be forgotten.

Superconductors really are super for high frequencies. There must be small scale applications where the refrigeration is worth the price. Preliminary measurements by Los Alamos and the University of Wuppertal in West Germany on materials in superconducting cavities suggest that the higher T_c superconductors are even less lossy than the now common lower T_c materials. We speculate that this is because there are actually fewer non-superconducting electrons present to cause residual losses. This may also provide clues as to why the T_c's are so high and as how to make them higher.

Conclusion

People who work in the field of superconductivity cannot tell if the public is being oversold on the promise of applications for the new superconductors. Indeed no one can see the future, but we can feel the excitement of the potential of these new materials. Turn your thinking loose on how to use these new specifications.

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James L. Smith received his B.S. in Physics in 1965 from Wayne State University in Detroit, MI and his Ph.D. in physics in 1974 from Brown University in Providence, RI. Since 1973 he has held various positions at the Los Alamos National Laboratory. He has published over a hundred papers on superconductivity.